

Efficacy of diode laser therapy on osseointegration of dental implants: A split-mouth clinical study

Laser therapy on osseointegration of dental implants

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Abstract

Aim: The purpose of the present study was to investigate the effect of low-level laser therapy (LLLT) on postoperative osseointegration and secondary stability in symmetrical dental implants.

Material and Methods: Patients with symmetrical missing teeth in the maxilla and mandible participated in the present study. Implants were reserved randomly into laser and control groups. Indium Gallium Arsenide Phosphide (InGaAsP) semiconductor diode laser with a wavelength of 940 nm (total array area 0.8 cm², contact probe diameter 1 cm, total power 200 mW, average power intensity 250 mW/cm², total energy 40 J, average energy intensity 50 J/cm²) was used in the study. The buccal, lingual, mesial, and distal sides of the dental implants were irradiated with a laser. Six sessions of LLLT were given to the laser group implants for 2 months. The stability of these implants was measured with Periotest®. The mean Periotest® values were recorded at baseline at 14, 30, and 90 days.

Results: No significant differences were observed among the groups in the Periotest® (Periotest®, Siemens AG, Bensheim, Germany) values at baseline (P=0.985). A larger decrease in the Periotest® values of the laser group was observed compared to the control group for 90 days. The Periotest® values on the 30th day (P=0.043) and the 90th day (P<0.001) were significantly lower in the laser group.

Discussion: LLLT application stimulates biological tissues and increases both the bone healing capacity and secondary stability of dental implants. LLLT enhances the long-term success of dental implants by strengthening osseointegration and allows early implant loading.

Keywords

Bone Density, Dental Implants, Diode Laser, Implant Stability, Osseointegration

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Introduction

Dental implant treatment has an important place in the rehabilitation of missing teeth. Implant-supported prostheses have been accepted by patients because they are more successful in terms of stability, aesthetics and functionality compared to conventional prostheses, and the popularity of this treatment method has gradually increased over the year. Although implant therapy is the preferred and effective treatment modality, this treatment modality depends on successful osseointegration during the healing period. The notion of osseointegration was first defined by Branemark as the connection of the implant surface to the bone [1]. Implant morphology, implant surface roughness and topography affect osseointegration [2]. Many studies have reported that immediate loading or early loading yielded near-success results when the osseointegration period was expected [3,4]. LLLT is used more and more in both medicine and dentistry to treat many medical conditions such as pain, wound healing and nerve injury. Understanding the effect of LLLT on bone remodeling is crucial to knowing whether LLLT will enhance implant-bone interaction. The laser, whose abbreviation is “Light Amplification by Stimulated Radiation Emission”, supports the inflammatory response by providing cellular biostimulation, thus accelerating the healing of tissues [5]. Although LLLT is known to stimulate cellular activity and increase tissue regeneration through biostimulation, clinical studies on the impact of LLLT on implant osseointegration are limited. The purpose of the present clinical research is to evaluate the effects of LLLT on the osseointegration of implants.

Material and Methods

Study Design

To address the research purpose, the authors designed and implemented a split-mouth, prospective, randomized, and double-blind clinical study. The present study was carried out on partially or totally edentulous patients who presented at the Erciyes University, Department of Oral and Maxillofacial Surgery, between January 2018 and January 2019 with the approval of the ethics committee. Healthy patients aged over 18 years, of both sexes, with symmetrical edentulous areas were included in the study. The following patients were excluded: patients under the age of 18 years, the presence of metabolic bone diseases, taking any kind of drugs, and non-symmetrical edentulous areas. There were 66 implants in the 22 patients included in this study. All patients signed informed consent forms. The control group consisted of 33 implants (21 mandibular and 12 maxillary) and the laser group consisted of 33 implants (21 mandibular and 12 maxillary). The study design is presented in Table 1. Cone beam computed tomography (CBCT) was taken from all patients after an intraoral examination.

Hounsfield Units (HU)

Implant recipient sites were evaluated for bone classification using the Simplant software (Simplant Pro 2011, Materialize, Leuven, Belgium). For bone density evaluation using the Hounsfield index, the same clinician (SB) evaluated implant sites from every patient’s CBCT scan. The average of these readings represented the density of that site. Table 1 shows

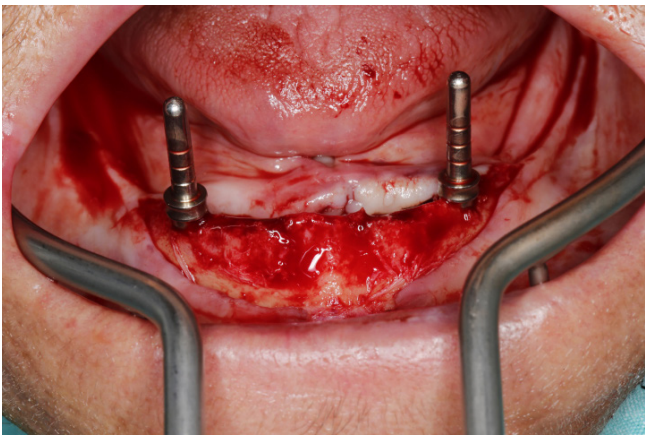


Figure 1. Implants of the same length and diameter were placed symmetrically with the same torque

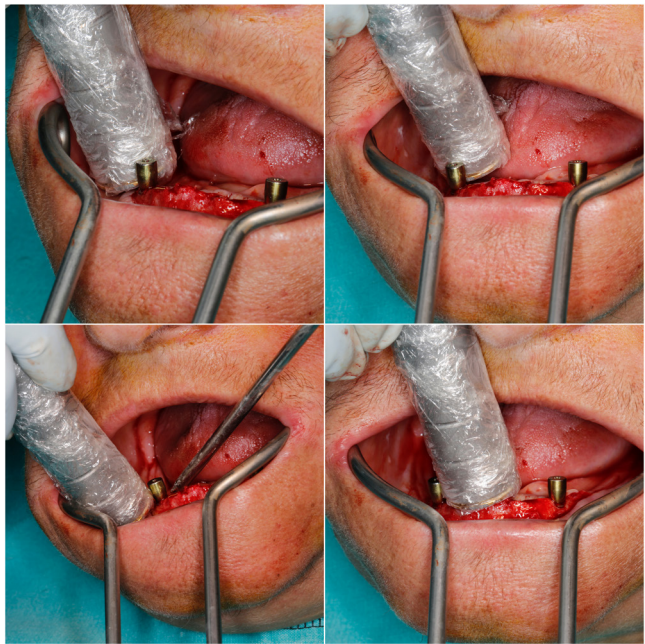


Figure 2. The laser was applied to four points as buccal, lingual, mesial and distal. Each application point received 200 seconds on the operation day and on the 3rd, 7th, 14th, 30th, 60th days postoperatively

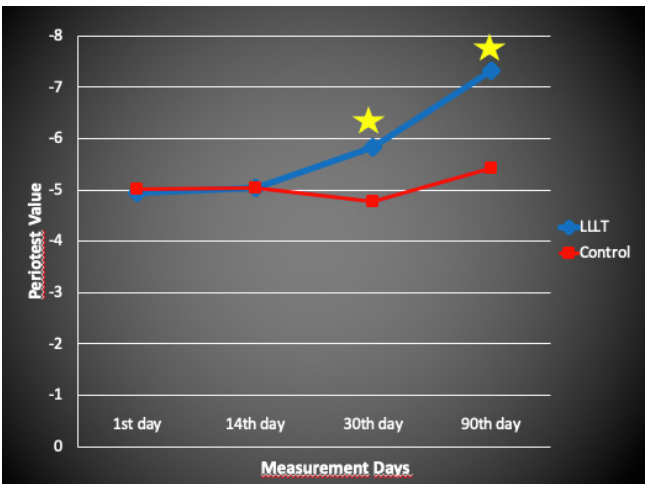


Figure 3. This graphic shows the trend of change in implant stability in the laser and control groups over time

the mean HU values of the patients. The HU values of the mandibular bones were over 600 HU, while these values were below 600 HU in the maxillary bones. The density of the bones of the patients in the laser and control group were similar to each other.

Surgical Protocol

Implantation sites had bilaterally similar bone density based on the HU. Following the mucosal incision, the mucoperiosteal flap was elevated. Drilling was performed at 800 rpm in both groups. Implants of the same length and diameter were placed symmetrically (Figure 1). All implants were placed with the same torque (60 rpm) by the same surgeon (SB). All patients received oral hygiene and post-operative care instructions.

LLLT Application

After implants placement, the implants were randomly selected for the laser and control groups by one clinician (SB). In the laser group, an InGaAsP semiconductor diode laser (BIOLASE Epic 10, Inc., Irvine, CA, USA) with a wavelength of 940 nm (total array area 0.8 cm², contact probe diameter 1 cm, total power 200 mW, average power intensity 250 mW/cm², total energy 40 J, average energy intensity 50 J/cm²) was used. Diode laser irradiation parameters were selected based on previous studies [6,7]. Four points were irradiated by a laser: buccal, lingual/palatal, mesial and distal sides of the implants with the tissue probe (Figure 2). Each application point received a total of 800 seconds with 200 seconds per side on the operation day, 3rd, 7th, and 14th days and the 1st and 2nd months postoperatively. The same process was applied to the other group with a diode laser in the ‘off’ mode.

Implant Stability Measurements

The stability of each implant was measured with the Periotest® device. The Periotest® records 16 strokes, eliminating imprecise accuracy to achieve reliable measurements. The Periotest® system evaluates mobility between -8 and +50. Values between -8 and +9 are considered the limits for osseointegration in the implant [8]. While measuring with the Periotest®, patients were sitting upright without leaning back. The Periotest® device evaluates the stabilization with the healing cap of the implants. To standardize the Periotest® measurements, all healing caps were given 10 Ncm torque with a rotary instrument. Periotest®

values were recorded immediately after implantation and on the 14th, 30th and 90th days postoperatively. The torque of the healing caps was checked before each measurement to avoid incorrect measurement. Each measurement was repeated three times by the same clinician (AED).

Statistical Analysis

Data normality was assessed using histograms, q-q plots, and the Shapiro-Wilk test. The variance homogeneity was examined using the Levene’s test. To compare differences among groups, either an independent two sample t-test and the Mann-Whitney U test, or the Kruskal-Wallis tests were applied for quantitative data. Fisher’s exact test was applied for qualitative data. Data values were expressed using mean ± standard deviation or frequencies (percentages). Coefficient of variation (CV) and intraclass correlation coefficient (ICC) were used for intra-examiner reliability. Analyses were conducted using Turcosa (Turcosa Analytics Ltd. Co., Turkey, www.turcosa.com.tr). A p-value less than 0.05 was considered statistically significant.

Results

CV values ranged between 3.7% and 4.4%, while ICC values ranged between 0.96 and 0.97, showing excellent agreement. Sixty-six implants were placed in the 22 patients (8 males and 14 females) enrolled in this study. The laser group consisted of 33 implants (21 mandibular, 12 maxillary) and the control group consisted of 33 implants (21 mandibular, 12 maxillary). Twenty-one mandibular and 12 maxillary implants received laser therapy. Patients were followed for 1 year both clinically and radiographically. On clinical examination, all implants in both groups were immobile and asymptomatic. None of the patients experienced implant failure.

Periotest® Value Results

No significant difference was observed between the Periotest® values at day 1 in the control and laser groups (p=0.985). On the 14th day, a decrease in the Periotest® values was observed in the laser group. However, these changes were not statistically significant (p=0.204). On the 30th day, the decrease in the Periotest® values of the implants in the laser group was statistically significant (p=0.043). According to Periotest® values, the stability of the implants was statistically lower in the laser group than in the control group on the 90th day (p<0.001) (Table 2).

Table 1. Summary of Study Variables

Demographic Variables			
Sample size, N	33		
Gender (Male %)	17 (51,5)		
Age (yr)	51.5 ± 6.88		
Predictor Variables			
Number of Implants (n=66)	Laser Group (n=33)	Control group (n=33)	
Maxilla, N	12	12	
Mandibula, N	21	21	
HU Value			P Value
Maxilla	405,76 ± 122,18	413,69 ± 127,42	0.301g
Mandibula	981,63 ± 210,04	983,64 ± 199,34	0.843g
Note: Data are presented as number (percentage) or mean ± standard deviation, g: T-test			

Table 2. Mean periotest value in the laser and control groups over time

Days of Periotest Measurement	Groups	Mean Periotest Values ± Standard Deviation	P Value
1st Day	Laser	-3.9182±2.9238	0.985g
	Control	-4.0242±2.6388	
14th Day	Laser	-4.2091±2.7765	0.204g
	Control	-3.3212±2.8431	
30th Day	Laser	-4.5864±2.5403	0.043g
	Control	-3.2636±2.6643	
90th Day	Laser	-6.0909±2.2680	<0.001g
	Control	-3.8485±2.8171	

Note: Data are presented as number (percentage) or mean ± standard deviation, g: T-test

Discussion

The long-term clinical success of dental implants is closely related to implant osseointegration. Implant failures mostly occur during the postoperative recovery period before the implant superstructure and mostly in the early period following the surgical procedure. It is considerable to control, direct and accelerate the healing that causes the implant to integrate with the bone in the postoperative period [9]. Osseointegration is an essential condition for dental implant success. Therefore, studies have focused on methods to improve healing at the bone-implant integration. Previous studies have reported positive effects of LLLT on bone healing [7]. LLLT exhibits analgesic, anti-inflammatory and healing properties, since its wavelengths and low energy densities can penetrate tissues. The laser energy provides direct biostimulation, by stimulating the molecules and atoms of cells. In experimental studies investigating the effectiveness of LLLT, it has been reported that the healing potential of the bone is promoted. However, there is little literature information about these impacts on implant osseointegration [10]. In animal studies in recent years, it has been shown that LLLT application after implant surgery increases osteoblast proliferation and thus has a positive effect on implant osseointegration [11]. In an *in vivo* study, an increase in intracellular ATP occurred in the group receiving laser therapy, and osteoblastic activity was also found to be increased due to increased intracellular metabolism. In another *in vitro* study, cells exposed to laser irradiation with therapeutic doses showed a significant increase in alkaline phosphatase, a marker of bone production, compared to control cells. All these studies demonstrate that LLLT increases osteogenic potential creating strong bio stimulation in cells [12,13].

Soleimani et al. concluded that the use of LLLT enhances the proliferation of mesenchymal stem cells and their differentiation into osteoblasts [14]. In Petri's study, gene expression alkaline phosphatase, osteocalcin, bone sialoprotein, and bone morphogenic protein-7 was higher in LLLT treated cultures, while runt-related transcription factor 2, osteopontin, and osteoprotegerin were lower compared to non-irradiated cells [9]. In present study, based on the knowledge that LLLT stimulates osteoblastic cell differentiation and the idea that it will show possible benefits in implant osseointegration, LLLT was applied to the peri-implant bone area after implant surgery. The basis of the biostimulant effect of LLLT on tissues is that it increases tissue oxygenation and nutrition by increasing ATP, DNA, RNA synthesis, and this condition results in a faster tissue regeneration activity. Jawad et al. reported the optimal efficacy of a nine hundred forty nanometer (nm) diode laser in stimulating osteoblast cells for improved bone formation [15]. Romao et al. applied laser to an alveolar bone socket after molar tooth extraction, and the results suggested that laser phototherapy could accelerate alveolar bone repair, leading to a more homologous trabecular design indicated by thin and close trabeculae. In light of these findings, a diode laser device that produces 940 nm wavelength laser beam was used in the jaw bones of patients included in the present study [16].

In the literature, the parameter used in laser studies for biostimulation is joule/square centimeter (J/cm^2) [6,7,10]. Although similar laser parameters were used in *in vitro*

and animal studies, it was seen that each researcher used different parameters in human studies. The effect of laser on the tissue was determined by the power (watt) of the laser, the application time (second), and the spot width (cm^2). The present study focused on the effect of LLLT using a 940 nm GaAlAs diode laser with an output power of 200 mW and an average energy intensity of $50 \text{ J}/\text{cm}^2$, on the osseointegration of implants placed into the maxilla and mandibula. The diode laser irradiation parameters were determined based on previous studies [6,7,10]. Although there are a large number of *in vitro* and animal studies on this subject, human studies are quite limited. The literature has shown that clinical studies on this subject have been conducted over the last 10 years. As far as we know, there are very few clinical studies about LLLT on the osseointegration of implants in the literature. In the study conducted by Garcia et al., LLLT was applied to implants in the mandible and the implant stability quotient was measured using resonance frequency analysis. It was found that implant stability quotient values gradually increased from week 6 to week 12 in the irradiated group. Gokmenoglu et al., used the light-emitting diode (LED) device at a wavelength of 626nm and they found that the stability values of the implants in the LED group did not change, while the stability values of the implants in the control group decreased over time [6]. Mandic et al., applied LLLT to implants placed in the maxillary bone [17]. The irradiated implants achieved higher stability than the implants in the control group during the follow-up, and the difference was statistically significant at the 5th postoperative week. In the study by Torkzaban et al., seven sessions of LLLT were irradiated on the buccal and palatal sides of implants [7]. While an increase was observed in the implants in the laser group over time, there was no statistically significant difference between the laser and control groups. These research studies focused on the potential of the laser to reduce the healing period following implantation and to improve the potential for bone regeneration. Although the stability values of the laser groups were higher than the control groups, the results were not statistically significant. Gokmenoglu et al. used forty-six joule/square centimeters energy intensity extraorally. No significant differences were demonstrated in the ISQ values between groups [6]. This may be due to insufficient energy penetration into the tissues due to the lower wavelength of the laser used. Torkzaban's study showed similar characteristics as the present clinical study [7]. They used nine hundred forty nanometers, and laser irradiation was applied at two points for forty seconds per point.

Implant stability values were measured using the Periotest® device due to its practical, non-invasive and simple nature. Clinicians prefer Periotest® because it provides accurate and repeatable measurements and ease of application. Implant stability values were measured and recorded during and after the operation on the 14th, 30th, and 90th days. In this study, the Periotest® values were almost the same in both groups at baseline (Laser Group: -3.91 ± 2.92 , Control Group: -4.02 ± 2.63). On the fourteenth day, an increase was observed in the laser group, however these changes were not statistically significant ($p=0.204$). The mean values of the thirtieth day were decreased in the laser group and there were statistically significant

differences between the groups ($p=0,043$). On the ninetieth day, the values were lower in the laser group, and the results were found statistically significant ($p<0,001$). In other studies, the difference in values in the laser and control groups was not significant. However, in this present study, statistically significant results were obtained [10,17]. The present outcomes can be explained as follows. A total of 6 sessions of laser were applied for 2 months. The wavelength of the diode laser device used was 940 nm. By using the laser device with a high wavelength, the penetration of the laser light into the tissues may have increased. Osteoblastic cell stimulation may be increased by applying the laser to 4 regions around the implants. Application of LLLT at optimal doses may increase the osseointegration of implants by promoting bone formation.

Conclusion

As a result of our findings, laser application stimulates biological tissues and accelerates bone healing. LLLT was found to be effective and successful in implant osseointegration. The weakness of this study is the limited study samples. On the other hand, the strengths of the present study are that it is split-mouth, prospective, randomized, and double-blind clinical study design. Implant stability values increased after six sessions of LLLT using the irradiation procedure in the present study. When the primary stability is insufficient, the secondary stability can be improved by using low-level laser. Although LLLT has been applied in the osseointegration of implants, there is no defined standard irradiation protocol and parameter. More studies are needed on this topic due to insufficient clinical studies.

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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